Using a Beam Plug to Reduce the Wrong-Sign Contribution to the NOvA Neutrino Flux

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April 2, 2006

Abstract

The possibility of using a beam plug in the NOvA medium-energy NuMI beam is considered as a way to improve the right-sign to wrong-sign ratio in anti-neutrino running. A beam plug capable of absorbing hadrons traveling at an angle less than 10 mrad improves the wrong-sign/right-sign ratio from 13.7% to 6.7% while reducing the right-sign event rate by 8.8% in the 1-3 GeV region.

1 Neutrino Fluxes with a Beam Plug

A beam plug is a passive slug of matter located on the beam axis to absorb pions and kaons directed on the beam axis to prevent these hadrons from producing neutrinos. The motivation for MINOS is to reduce the neutral-current feed down from the high-energy tail of the low energy neutrino spectrum. For NOvA, who's off-axis location makes good use of the on-axis hadrons, the motivation is to reduce the unfocused component of the neutrino beam and reduce the wrong-sign contribution to the ν_e appearance signal in anti-neutrino running. The issue is illustrated in Figure 1 which shows the ν_μ event rates expected at the NOvA Ash River site separately for neutrinos and anti-neutrinos when the horns are set to focus negative beams. In the default NuMI configuration, wrong-sign muons are roughly xxx% of the total rate in the 1-3 GeV region.

In this short note, I investigate at the generator level the possibility on using a beam plug to improve the right-sign fraction of the neutrino spectrum. The plug is modeled very simply. Figure 2 shows the ν_μ event rate produced at the Ash River detector as a function of the parent hadron production angle. As seen in the plot, the wrong-sign component arises from hadrons which travel along the beam axis and see no horn focusing. The plug is modeled by assuming that all

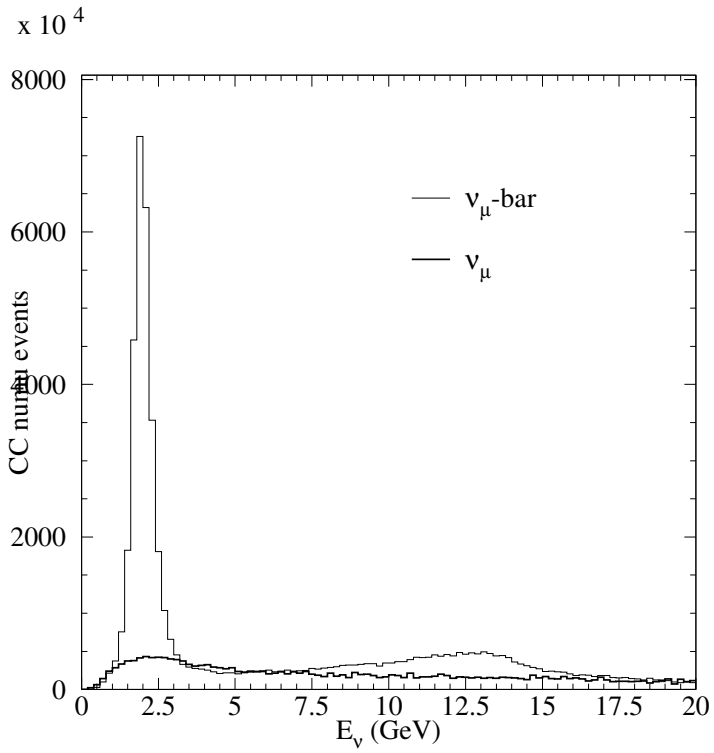

Figure 1: The anti-neutrino fluxes at the Ash River site before oscillations. Spectra are shown separately for anti-neutrinos and neutrinos.

hadrons within a certain angle can be absorbed and the spectra are generated by removing hadrons that travel within 5, 10, 15, and 20 mrad of the beam axis. Results are shown in Figure 2 and summarized in Table 1.

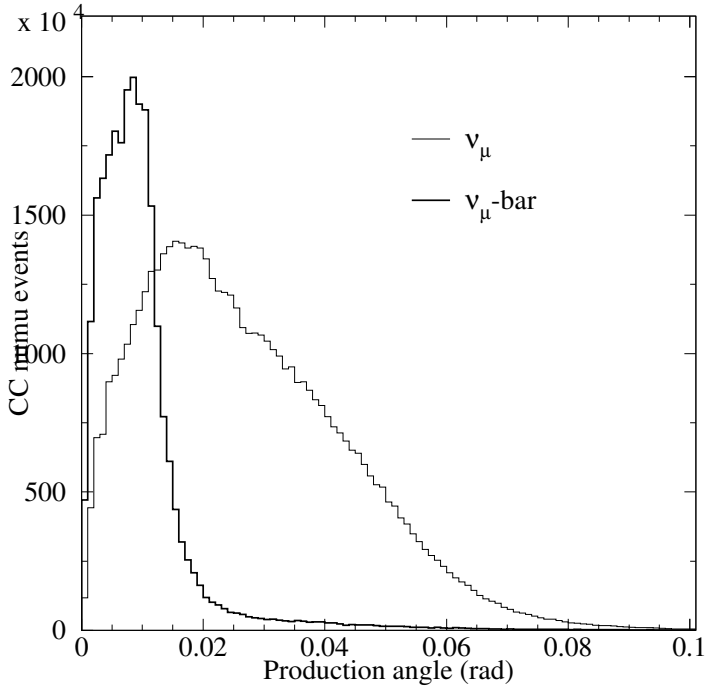

Figure 2: The production angle of parent hadrons at the target weighted by their contribution to the spectrum at the Ash River site. Distributions are shown separately for anti-neutrinos and neutrinos.

	Event Rate			Rate Reduction (%)	
Plug Angle (mrad)	$\bar{\nu}_\mu$	ν_μ	$\nu_\mu/\bar{\nu}_\mu$	$\bar{\nu}_\mu$	ν_μ
0	17.1	2.35	13.7	0	0
5	16.6	1.64	9.9	2.9	30.2
10	15.6	1.04	6.7	8.8	55.7
15	14.1	0.69	4.9	17.5	70.6
20	12.4	0.51	4.1	27.5	78.3

Table 1: Summary of idealized plug performance for NOvA in during anti-neutrino running.

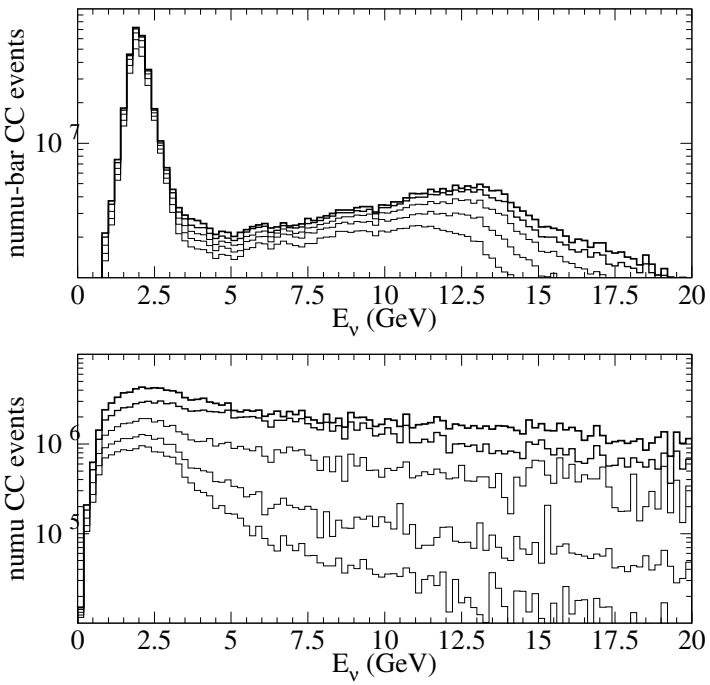

Figure 3: The neutrino and anti-neutrino spectra at the ash river site for beam plugs set to remove angles ranging from 20 mrad to 0 in steps of 5 mrad. Largest plug angles produce the lowest fluxes.

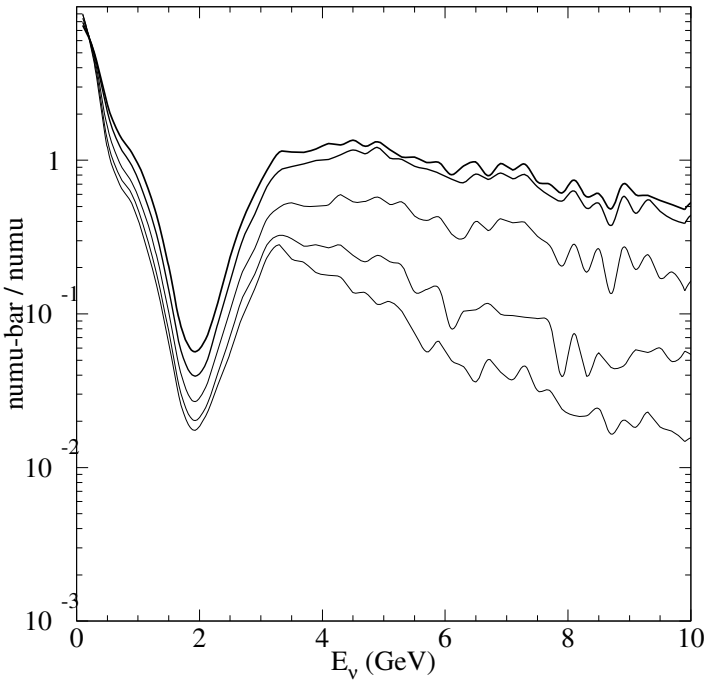

Figure 4: The ratio of anti-neutrino event rates to neutrino event rates as a function of plug angle. Angles range from 20 mrad to 0 mrad in steps of 5 mrad.